

APPENDIX E

SURFACE ANALYSIS CALCULATIONS

APPENDIX E – SURFACE ANALYSIS CALCUALTIONS

OVERVIEW

Using the 1992 NLCD classifications obtained from the AERSURFACE User’s Guide, the land cover data from 2006 were reclassified to reasonably equivalent 1992 NLCD classifications using documentation from the NLCD 1992/2001 Retrofit Land Cover Change Product. The NLCD 1992/2001 Retrofit Land Cover Change Product is also appropriate for use with the 2006 NLCD. The reclassification was based on the NLCD 1992-2001 Anderson Level I Cross-walk Table which is in Figure E-1: *NLCD 1992-2001 Anderson Level I Cross-walk*.

NLCD 1992 Class Code	NLCD 1992 Description	NLCD 2001 Class Code	NLCD 2001 Description	Modified Anderson Level I
11	Open Water	11	Open Water	1
12	Perennial Ice, Snow	12	Perennial Ice, Snow	8
85	Urban, Recreational Grasses	21	Developed, Open Space	2
21	Low Intensity Residential	22	Developed, Low Intensity	2
22	High Intensity Residential	23	Developed, Medium Intensity	2
23	Commercial, Industrial, Trans.	24	Developed, High Intensity	2
31	Bare Rock, Sand	31	Barren Land, Rock, Sand, Clay	3
		32	Unconsolidated Shore*	3
32	Quarry, Strip Mine, Gravel Pit	31	Barren Land, Rock, Sand, Clay	3
33	Transitional Barren	31	Barren Land, Rock, Sand, Clay	3
33	Transitional Barren	31	Barren Land, Rock, Sand, Clay	3
41	Deciduous Forest	41	Deciduous Forest	4
42	Evergreen Forest	42	Evergreen Forest	4
43	Mixed Forest	43	Mixed Forest	4
		51	Dwarf Scrub**	8
51	Shrubland	52	Shrub, Scrub	5
61	Orchards, Vineyards, Other			6
71	Grasslands, Herbaceous	71	Grassland, Herbaceous	5
		72	Sedge, Herbaceous**	8
		73	Lichens**	8
		74	Moss**	8
81	Pasture, Hay	81	Pasture, Hay	6
82	Row Crops	82	Cultivated Crops	6
83	Small Grains	82	Cultivated Crops	6
84	Fallow	82	Cultivated Crops	6
85	Urban, Recreational Grasses	21	Developed, Open Space	2
91	Woody Wetlands	90	Woody Wetlands	7
92	Emergent, Herbaceous Wetland	95	Emergent Herbaceous Wetlands	7
		91	Palustrine Forested Wetland*	7
		92	Palustrine Scrub/Shrub Wetland*	7
		93	Estuarine Forested Wetland*	7
		94	Estuarine Scrub/Shrub Wetland*	7
		96	Palustrine Emergent Wetland*	7
		97	Estuarine Emergent Wetland*	7
		98	Palustrine Aquatic Bed*	7
		99	Estuarine Aquatic Bed*	7
			* Coastal Areas Only	
			** Alaska Only	

Figure E-1: NLCD 1992-2001 Anderson Level I Cross-walk

A rectangular area extending 5 km from and centered on the Exide site was extracted from the 2006 NLCD product and reclassified using ESRI ArcGIS software. The noontime albedo and Bowen ratio were calculated using this study area. A circular area extending 1 km from and centered on the Exide site was extracted from the 2006 NLCD product and reclassified using ESRI ArcGIS software in order to calculate the surface roughness length. The rectangular and circular areas used for the calculations are graphically depicted below.



Figure E-2: Rectangular Area Extracted from 2006 NLCD.



Figure E-3: Circular Area Extracted from 2006 NLCD.

The annual average noontime albedo, Bowen ratio, and surface roughness length values calculated are based on values obtained from the AERSURFACE User's Guide. The surface characteristic values vary by land use classification and season of the year. The calculations used the default season assignments for each month listed in the AERSURFACE User's Guide. A description of each season and assignments for each month are listed in Table E-1: *Seasonal*

Category Descriptions. Since there is rarely an extended period of snow cover in north central Texas, seasonal category 4 was not used.

Table E-1: Seasonal Category Descriptions

Seasonal Category	Season Description	Default Month Assignments
1	Midsummer with lush vegetation	June, July, August
2	Autumn with unharvested cropland	September, October, November
3	Late autumn after frost and harvest, or winter with no snow	December, January, February
4	Winter with continuous snow on ground	December, January, February
5	Transitional spring with partial green coverage or short annuals	March, April, May

NOONTIME ALBEDO CALCULATION

The calculation of the noontime albedo was based on a simple unweighted arithmetic mean (i.e., no direction or distance dependency) of each land use classification for a representative domain defined by a 10km by 10km region (analysis area) centered on the Exide site. In the NLCD 2006, the analysis area is represented as a group of rasters, (i.e., rows and columns), each representing a 30 meter by 30 meter area. The fraction of area for each land use classification was calculated by counting the number of rasters for each land use classification and dividing by the total number of rasters in the analysis area. The fraction of area for each land use classification was multiplied by the appropriate noontime albedo value for that land use classification. The annual average noontime albedo value for the analysis area is the sum of the values for each land use classification.

The calculation of the annual average noontime albedo value for each land use classification is depicted in Table E-2: *Noontime Albedo Values By Month*. The calculation of the annual average noontime albedo value of the analysis area is depicted in Table E-3: *Calculation of Annual Average Noontime Albedo for Analysis Area*.

Table E-2: Noontime Albedo Values By Month

Land Use Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
11	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
21	0.18	0.18	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.18	0.165
22	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18

Land Use Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
23	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
31	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
33	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
41	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.1625
42	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
43	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
51	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
71	0.2	0.2	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.2	0.185
81	0.18	0.18	0.14	0.14	0.14	0.2	0.2	0.2	0.2	0.2	0.2	0.18	0.18
82	0.18	0.18	0.14	0.14	0.14	0.2	0.2	0.2	0.2	0.2	0.2	0.18	0.18
83	0.18	0.18	0.14	0.14	0.14	0.2	0.2	0.2	0.2	0.2	0.2	0.18	0.18
85	0.18	0.18	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.18	0.1575
91	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
92	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14

Table E-3: Calculation of Annual Average Noontime Albedo for Analysis Area

Land Use Code	Area By No. of Rasters	AreaFraction (AF)	albedo	AF*albedo
11	407	0.0037	0.1	0.0004
21	23568	0.2116	0.165	0.0349
22	32966	0.2960	0.18	0.0533
23	5774	0.0518	0.18	0.0093
31	34	0.0003	0.2	0.0001
41	4219	0.0379	0.1625	0.0062
42	69	0.0006	0.12	0.0001
71	20972	0.1883	0.185	0.0348

Land Use Code	Area By No. of Rasters	AreaFraction (AF)	albedo	AF*albedo
81	5264	0.0473	0.18	0.0085
82	7778	0.0698	0.18	0.0126
85	10217	0.0917	0.1575	0.0145
91	74	0.0007	0.14	0.0001
92	18	0.0002	0.14	0.0000
TOTAL	111360	1		0.1747

BOWEN RATIO CALCULATION

The calculation of the Bowen ratio was based on a simple unweighted geometric mean (i.e., no direction or distance dependency) for the same analysis area as used in the calculation of noontime albedo. The fraction of area for each land use classification was calculated by counting the number of rasters for each land use classification and dividing by the total number of rasters in the analysis area. The fraction of area for each land use classification was multiplied by the natural logarithm of the appropriate average Bowen ratio value for that land use classification. The annual average Bowen ratio value for the analysis area is geometric mean of the values for each land use classification.

Then geometric mean was calculated using the formula:

Geometric Mean = $\exp(\sum w_i \ln(x_i) / \sum w_i)$, where w_i is the fraction of area and x_i is the average Bowen ratio value for a given land use classification.

The calculation of the annual average Bowen ratio value for each land use classification is depicted in Table E-4: *Average Bowen Ratio Values By Month*. The calculation of the annual average Bowen ratio value of the analysis area is depicted in Table E-5: *Calculation of Annual Average Bowen Ratio for Analysis Area*.

Table E-4: Average Bowen Ratio Values By Month

Land Use Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
11	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
21	1	1	0.8	0.8	0.8	0.8	0.8	0.8	1	1	1	1	0.9
22	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
23	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
31	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5

Land Use Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
33	1	1	1	1	1	1	1	1	1	1	1	1	1
41	1	1	0.7	0.7	0.7	0.3	0.3	0.3	1	1	1	1	0.75
42	0.8	0.8	0.7	0.7	0.7	0.3	0.3	0.3	0.8	0.8	0.8	0.8	0.65
43	0.9	0.9	0.7	0.7	0.7	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.7
51	1.5	1.5	1	1	1	1	1	1	1.5	1.5	1.5	1.5	1.25
71	1	1	0.4	0.4	0.4	0.8	0.8	0.8	1	1	1	1	0.8
81	0.7	0.7	0.3	0.3	0.3	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.55
82	0.7	0.7	0.3	0.3	0.3	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.55
83	0.7	0.7	0.3	0.3	0.3	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.55
85	0.7	0.7	0.3	0.3	0.3	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.55
91	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.225
92	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table E-5: Calculation of Annual Average Bowen Ratio for Analysis Area

Land Use Code	AreaFraction (w_i)	Bowen ratio (x_i)	$w_i \ln(x_i)$
11	0.0037	0.1	-0.0084
21	0.2116	0.9	-0.0223
22	0.2960	1.5	0.1200
23	0.0518	1.5	0.0210
31	0.0003	1.5	0.0001
41	0.0379	0.75	-0.0109
42	0.0006	0.65	-0.0003
71	0.1883	0.8	-0.0420
81	0.0473	0.55	-0.0283
82	0.0698	0.55	-0.0418
85	0.0917	0.55	-0.0549

Land Use Code	AreaFraction (w_i)	Bowen ratio (x_i)	$w_i \ln(x_i)$
91	0.0007	0.225	-0.0010
92	0.0002	0.1	-0.0004

Using the formula for the geometric mean and the values in Table E-5, the calculated Bowen ratio is 0.9334.

SURFACE ROUGHNESS CALCULATION

The calculation of the surface roughness length was based on an inverse distance weighted geometric mean for a circular area centered on the Exide site with a radius of 1 km. The weighting factor is calculated by dividing the area fraction of a land use classification by the distance the fractional area is from the center point of the analysis area. This calculation was performed for each raster (30 meter by 30 meter area) within the 1 km circular analysis area. The weighting factor for each raster was multiplied by the natural logarithm of the appropriate surface roughness length value for that land use classification. The annual average surface roughness length value for the 1 km circular analysis area is the geometric mean of the values for each land use classification.

The calculation of the annual average surface roughness length value for each land use classification is depicted in Table E-6: *Surface Roughness Length Values By Month*. Since the calculation was performed for each raster in the analysis area (3498 rasters in all), a portion of the calculation of the annual average surface roughness length of the analysis area is depicted in Table E-7: *Calculation Sample of Surface Roughness Length for Analysis Area*. The area fraction value is not displayed since each raster comprises the same area fraction (1/3498). The geometric mean was calculated using the same formula as in calculating the Bowen ratio.

Table E-6: Surface Roughness Length Values By Month

Land Use Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
11	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
21	0.5	0.5	0.52	0.52	0.52	0.54	0.54	0.54	0.54	0.54	0.54	0.5	0.525
22	1	1	1	1	1	1	1	1	1	1	1	1	1
23	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
31	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
33	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
41	0.6	0.6	1	1	1	1.3	1.3	1.3	1.3	1.3	1.3	0.6	1.05
42	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
43	0.95	0.95	1.15	1.15	1.15	1.3	1.3	1.3	1.3	1.3	1.3	0.95	1.175
51	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Land Use Code	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
71	0.01	0.01	0.05	0.05	0.05	0.1	0.1	0.1	0.1	0.1	0.1	0.01	0.065
81	0.02	0.02	0.03	0.03	0.03	0.15	0.15	0.15	0.15	0.15	0.15	0.02	0.0875
82	0.02	0.02	0.03	0.03	0.03	0.2	0.2	0.2	0.2	0.2	0.2	0.02	0.1125
83	0.02	0.02	0.03	0.03	0.03	0.15	0.15	0.15	0.15	0.15	0.15	0.02	0.0875
85	0.01	0.01	0.015	0.015	0.015	0.02	0.02	0.02	0.015	0.015	0.015	0.01	0.015
91	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.675
92	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table E-7: Calculation Sample of Surface Roughness Length for Analysis Area

RASTER ID	Land Use Code	Distance (meters)	(Area Frac/Dist) w_i	Surface Roughness Length (meters)	$w_i \ln(x_i)$
44714	21	997.491	0.000287	0.525	-0.00018
44715	21	994.2141	0.000288	0.525	-0.00019
44716	21	991.7607	0.000288	0.525	-0.00019
44717	21	990.1369	0.000289	0.525	-0.00019
44718	21	989.3466	0.000289	0.525	-0.00019
44719	21	989.392	0.000289	0.525	-0.00019
44720	21	990.2729	0.000289	0.525	-0.00019
44721	21	991.9871	0.000288	0.525	-0.00019
44722	21	994.5303	0.000287	0.525	-0.00019
44723	21	997.8961	0.000286	0.525	-0.00018
45057	21	995.7499	0.000287	0.525	-0.00018
45058	85	988.2906	0.000289	0.015	-0.00121
45059	85	981.6175	0.000291	0.015	-0.00122
45060	21	975.7467	0.000293	0.525	-0.00019

RASTER ID	Land Use Code	Distance (meters)	(Area Frac/Dist) w_i	Surface Roughness Length (meters)	$w_i \ln(x_i)$
45061	21	970.6927	0.000295	0.525	-0.00019
45062	21	966.4683	0.000296	0.525	-0.00019
45063	21	963.0846	0.000297	0.525	-0.00019

Using the formula for the geometric mean and the values in Table E-7, the calculated annual average surface roughness length is 0.2625 meters.

EQUIVALENCY WITH AERSURFACE

In order to test for equivalency with AERSURFACE, the ADEC method was performed using the NLCD 1992 data and then compared to results from AERSURFACE. If AERSURFACE calculates equivalent values as the ADEC method, the two procedures are equivalent.

The calculations of the annual average noontime albedo, Bowen ratio, and surface roughness length values using the ADEC method with NLCD 1992 are in Table E-8: *Calculation of Noontime Albedo with NLCD 1992 Data*, Table E-9: *Calculation of Average Bowen Ratio with NLCD 1992 Data*, and Table E-10: *Sample of Surface Roughness Length with NLCD 1992 Data*, respectively. Figure E-4: *AERSURFACE Log File* depicts the AERSURFACE output using the same input as the ADEC method.

The calculated noontime albedo value is 0.1749. Using the equation for the geometric mean, the Bowen ratio value is 0.5931 and the surface roughness length value is 0.1386 meters. AERSURFACE calculated a noontime albedo value of 0.17, a Bowen ratio value of 0.59, and a surface roughness length of 0.133 meters. The noontime albedo and Bowen ratio values are equivalent. There is a slight difference in the surface roughness length values. An explanation of the discrepancy in the surface roughness values is that different methodologies were used to calculate the distance of each raster to the center point of the 1 km circular area. From review of the AERSURFACE source code, AERSURFACE calculates distance as the straight line planar distance between two points. The ArcGIS software calculates the geodesic distance between two points. The geodesic distance takes into consideration the curvature of the spheroid approximating the curvature of the earth. Given that this difference is approximately 4%, the surface roughness lengths are considered equivalent.

Table E-8: Calculation of Noontime Albedo with NLCD 1992 Data

Land Use Code	Area By No. of Rasters	AreaFraction (AF)	albedo	AF*albedo
11	550	0.0049	0.1	0.0005
21	4469	0.0401	0.165	0.0066
22	1570	0.0141	0.18	0.0025

Land Use Code	Area By No. of Rasters	AreaFraction (AF)	albedo	AF*albedo
23	1513	0.0136	0.18	0.0024
31	30	0.0003	0.2	0.0001
41	4147	0.0372	0.1625	0.0061
42	5525	0.0496	0.12	0.0060
71	3391	0.0305	0.185	0.0056
81	47972	0.4308	0.18	0.0775
82	25544	0.2294	0.18	0.0413
85	498	0.0045	0.1575	0.0007
92	1	0.0000	0.14	0.0000
33	8	0.0001	0.18	0.0000
43	1540	0.0138	0.14	0.0019
51	199	0.0018	0.18	0.0003
83	14403	0.1293	0.18	0.0233
TOTAL	111360	1		0.1749

Table E-9: Calculation of Average Bowen Ratio with NLCD 1992 Data

Land Use Code	AreaFraction (w_i)	Bowen ratio (x_i)	$w_i \ln(x_i)$
11	0.0050	0.1	-0.0114
21	0.0402	0.9	-0.0042
22	0.0141	1.5	0.0057
23	0.0136	1.5	0.0055
31	0.0003	1.5	0.0001
41	0.0373	0.75	-0.0107
42	0.0497	0.65	-0.0214

Land Use Code	AreaFraction (w_i)	Bowen ratio (x_i)	$w_i \ln(x_i)$
71	0.0305	0.8	-0.0068
81	0.4318	0.55	-0.2582
82	0.2299	0.55	-0.1375
85	0.0045	0.55	-0.0027
92	0.0000	0.1	0.0000
33	0.0001	1	0.0000
43	0.0139	0.7	-0.0049
51	0.0018	1.25	0.0004
83	0.1297	0.55	-0.0775

Table E-10: Calculation Sample of Surface Roughness Length with NLCD 1992 Data

RASTER ID	Land Use Code	Distance (meters)	(Area Frac/Dist) w_i	Surface Roughness Length (meters)	$w_i \ln(x_i)$
44363	21	998.1735	0.000287	0.525	-0.00018
44364	21	991.7549	0.000289	0.525	-0.00019
44365	21	986.2195	0.00029	0.525	-0.00019
44366	21	981.5823	0.000292	0.525	-0.00019
44367	21	977.8561	0.000293	0.525	-0.00019
44368	21	975.0512	0.000294	0.525	-0.00019
44369	22	973.1758	0.000294	1	0
44370	22	972.235	0.000295	1	0
44371	22	972.2318	0.000295	1	0
44372	21	973.166	0.000294	0.525	-0.00019
44373	22	975.035	0.000294	1	0

RASTER ID	Land Use Code	Distance (meters)	(Area Frac/Dist) w_i	Surface Roughness Length (meters)	$w_i \ln(x_i)$
44374	21	977.8334	0.000293	0.525	-0.00019
44375	21	981.5533	0.000292	0.525	-0.00019
44376	21	986.1842	0.00029	0.525	-0.00019
44377	21	991.7134	0.000289	0.525	-0.00019
44378	21	998.126	0.000287	0.525	-0.00018
44708	81	994.2528	0.000288	0.0875	-0.0007

** Generated by AERSURFACE, dated 08009
 ** Center UTM Easting (meters): 702659.7
 ** Center UTM Northing (meters): 3668772.1
 ** UTM Zone: 14 Datum: NAD27
 ** Study radius (km) for surface roughness: 1.0
 ** Airport? N, Continuous snow cover? N
 ** Surface moisture? Average, Arid region? N
 ** Month/Season assignments? Default
 ** Late autumn after frost and harvest, or winter with no snow: 12 1 2
 ** Winter with continuous snow on the ground: 0
 ** Transitional spring (partial green coverage, short annuals): 3 4 5
 ** Midsummer with lush vegetation: 6 7 8
 ** Autumn with unharvested cropland: 9 10 11
 **
 FREQ_SECT ANNUAL 1
 SECTOR 1 0 360
 ** Sect Alb Bo Zo
 SITE_CHAR 1 1 0.17 0.59 0.133

Figure E-4: AERSURFACE Log File